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A sampling technique for signals of fractal nature: Application to top soil magnetic susceptibility measurements.

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Soils are often inhomogeneous as cavities, stones and roots cause density differences, which influence in-situ soil magnetic susceptibility measurements resulting in deviations from the mean value. In addition, non-uniform distribution of minerals and organic matter in the soil can be the reason of very local outliers in the order of some centimetres. The determination of a mean value is hence difficult as inhomogeneities may occur at all length scales. Considering small areas, in the order of some tens of square metres, susceptibility mapping is commonly performed on a close-meshed grid, which does not require taking into account variations around each grid point. When dealing with larger areas, in the order some square kilometres, the distance between each grid point is of course also much larger, and it is therefore important that the susceptibility at each grid point represents a well established mean, close to the true but unknown value. Our aim is to test if a random measurement scheme is appropriate for the determination of a well estimated mean or if another type of measurement scheme, taking into account a possible fractal nature, may be better.

Here we present a new measurement scheme, hereafter called scaled sampling, for the establishment of representative mean values at grid point level. Scaled sampling calculates mean values of different randomly chosen subsets at different length scales. Then, a weighted mean from all subsets is determined. The generation of such subsets has two advantages compared to random sampling: First, one can introduce weights and subsets with larger standard deviations will have therefore less influence on the final weighted mean. Second, different length scales are considered.

We used first a synthetic data set consisting of a constant value with superposed randomly occurring outliers for simulating scaled and random sampling. One random mean sample was defined as arithmetic mean of 12 randomly chosen points, while one scaled mean sample was defined as weighted mean of 4 random subsets containing 3 individual points each. This was repeated 600 times to obtain representative histograms. Both sampling schemes yielded a Gaussian distribution of mean values, but scaled sampling resulted in a standard deviation that is fifteen times smaller compared to that of random sampling.

Second, we tested both sampling schemes on a real data set, which was obtained by measuring the top soil magnetic susceptibility with a MS3 Bartington system along a 100 metre long profile. We chose a wood soil which had formed on carbonate rocks and iron bearing sediments and which is far off from industry and traffic, being uninfluenced by human activity for at least 60 years. Profile resolution was limited by the sensor (MS2D) diameter, i.e. 20 cm, so that the profile consists only of 501 points. We applied a box counting algorithm to determine the capacity dimension of the data set. A value of 1.42 indicates that the measured susceptibility values are not randomly distributed along the profile and that random sampling would not be appropriate in this case. Finally, we simulated random and scaled sampling as described above. Indeed, random sampling failed because a Gaussian distribution of values was obtained, but such one is not seen in the histogram of the measured data. In contrast, scaled sampling reflected well the distribution of measured values.

It can be concluded that scaled sampling is a better method than random sampling when data is of fractal nature. Scaled sampling may be applied to other types of data and materials such as for instance geochemical soil data, but also when determining chemical properties from thin sections.